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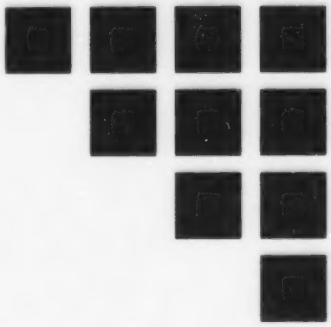
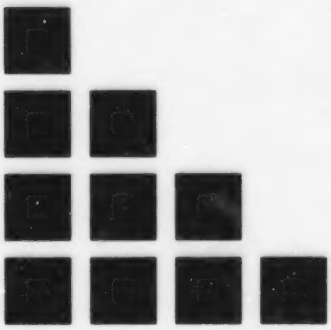


The Impact of Inequality on Productivity Growth: A Primer

R-00-3E
by
Huw Lloyd-Ellis
May 2000

Research Paper



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Abstract

This primer reviews and clarifies recent theoretical and empirical work on the impacts of inequality on growth, and assesses the implications for human capital policy in Canada. In the presence of certain fundamental market failures (e.g. borrowing constraints, non-tradeable human capital and knowledge spillovers) the distribution of wealth and/or human capital are crucial determinants of productivity growth. The empirical evidence suggests that any negative impacts of inequality on productivity growth in advanced economies are likely to be long term in nature, operation via implicit long term borrowing constraints and intergenerational externalities. A key factor is the impact of parental resources on their children's capacity to get the most out of the public education system. Parents provide key complementary inputs but typically cannot borrow against their children's anticipated earnings in order to finance them. The most effective growth-promoting policies are often those that are also equality-promoting and the most cost-effective education policies are those that enhance the capacity of children to get the most out of the public system at an early stage.

Sommaire

Cet article présente les travaux théoriques et empiriques portant sur les impacts de l'inégalité des revenus ou de la richesse sur la croissance économique et en évalue les implications pour les politiques canadiennes du capital humain sont aussi présentées. Certaines inefficacités du marché ne peuvent être corrigées, par exemple : les contraintes de crédits, l'impossibilité de négocier le capital humain ainsi que les effets de débordement ; en présence de ces inefficacités, la distribution du patrimoine, ainsi que celle du capital humain, détermine la croissance de la productivité. Les résultats de l'analyse empirique indiquent que la répartition inégale de la richesse a des conséquences négatives à long terme sur la croissance de la productivité dans les pays à l'économie développée via des contraintes budgétaires et des effets intergénérationels. Les ressources dont disposent les parents ont un effet marquant sur la capacité des enfants à bénéficier de l'éducation publique. Les parents ne peuvent utiliser les revenus futurs des enfants en garantie d'emprunts servant à leur offrir un milieu plus favorable à l'apprentissage scolaire. Les politiques économiques ayant le plus grand effet bénéfique sur la croissance sont fréquemment celles qui contribuent à favoriser l'égalité entre individus ; les politiques scolaires les plus efficaces en termes de coût sont celles qui accroissent la capacité des jeunes enfants à bénéficier du système scolaire public.

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1. Introduction

Although a discussion of the impacts of the distribution of wealth and skills on productivity growth may seem a rather abstract pursuit, the central issues involved are the subject of frequent media discussion and public debate. Should the tax system be more or less progressive? Should governments play an active role in subsidizing small businesses? Should the tuition costs paid by students in higher education be allowed to rise even further, or should higher education be completely subsidized? How should limited public resources be allocated between basic and higher education? Should primary and secondary education be funded at the national, provincial or municipal level? What determines the persistence of poverty from parent to child? How can governments best break this cycle? To what extent is the recent rise in the returns to education and experience linked to the growth of the knowledge economy or globalization? What does the lack of a supply-side response to this rise in returns to skill imply for human capital policy in Canada?

In a world in which a perfectly functioning market existed for *all* commodities and in which there were no impediments to trade, there would be no fundamental relationship between inequality and productivity or productivity growth.[1] In such a world, the only relationship would come from policy attempts to affect the distribution of income that also distort incentives. For example, a progressive income tax which reduces inequality while distorting the labour-leisure choice would reduce productivity. It is this view of the world that underlies the so-called "equity-efficiency" trade-off, that was the predominant view in the 1970s.[2] A fundamental (i.e. not policy-induced) relationship between inequality and productivity growth can only arise when there exists some kind of market failure. That is, for some reason a "commodity" is not being

[1] The existence of a market for *all* commodities is a rather tall order. This is especially true when we think about the market for human capital. For example, suppose secretary A can type 60 words per minute and secretary B can type 40 words per minute. The existence of a perfect market for this type of human capital (i.e. typing speed) would imply that secretary A could sell an "increment" of his/her typing speed to secretary B, so that after the trade both would type 50 words per minute. Another implication of such "complete markets" would be that poor parents could finance a mortgage in a rich neighbourhood with a high quality local school and low crime, etc., by borrowing against the resulting expected increase in their child's expected future earnings.

[2] See Osberg (1995) for a discussion. This tradeoff presumes an attempt to generate lower inequality relative to the laissez faire efficient economy. It is worth noting that distortionary policies which *increase* income inequality relative to the laissez faire economy would also reduce productivity.

priced correctly by the market, so that the marginal benefit of the commodity to society does not reflect the marginal cost of providing it.

In recent years, the simultaneous development of two branches of economics has lead to an increased acceptance of the importance of certain market failures in the growth process and, hence, for there to be a potential role for inequality in that process. Organizational Economics emphasizes informational problems that result in fundamental breakdowns in the market mechanism which cannot easily be solved.[3] This branch of economics has made significant ground in understanding the interaction of various non-market institutions (e.g. contracts and modes of organization) with the process of economic development. Endogenous Growth Theory emphasizes the role of positive externalities from private investments made by individual firms or households on the productivity of investments made by others (either contemporaneously or in the future), which are not taken into account by the investor. This branch of economics has made important advances in identifying the key determinants of long-run productivity growth and in providing a framework for thinking about the role of policy in influencing this growth.[4]

In addition to the direct impact of inequality on productivity, both branches have also emphasized factors affecting the persistence of inequality through time, and between generations. If wealth inequality is a temporary phase in the development process, then its implications for long-run productivity may be less important. However, if inequality persists through time and across generations, the overall effects are magnified. The issue of persistence is especially important from a policy perspective. Policies which reduce current inequality may well generate distortions in current output (via the traditional "equity-efficiency trade-off" story), but have positive effects on future productivity. The dynamic trade off between these effects depends not only on the direct impact of inequality on productivity, but also in large part on the persistence of inequality over time.

The objective of this primer is to review and clarify the key mechanisms through which inequality of wealth and/or human capital are thought to impact upon productivity and

[3] Organizational economics is often referred to as New Institutional Economics by development economists (see Hoff, Braverman and Stiglitz, 1993) and managerial economics by business economists (see Milgrom and Roberts, 1992).

[4] For an excellent introduction to endogenous growth theory, see Aghion and Howitt (1998).

productivity growth. It also lays out and discusses the empirical evidence relating to each mechanism and identifies which are most likely to be relevant for productivity growth in Canada. Finally, it spells out the main policy objectives suggested by the literature and identifies the main instruments through which they may be attained. Rather than presenting an exhaustive survey of what is now an extremely large literature, I focus on the mechanisms that economists tend to view as the most important and empirically relevant. The primer is intended to provide the reader with an understanding of how the various mechanisms work, the evolution of thinking behind them and the extent to which they have been evaluated empirically.

The layout of the primer reflects the general evolution in emphasis from the role of credit market imperfections and wealth inequality (Section 3), to human capital externalities (Section 4) and the impact of the education system (Section 5) and, more recently, to the interactions between technological change and the acquisition of skills (Section 6). In Section 7, I briefly discuss other mechanism which seem less important for Canada, and in Section 8 the implications of the literature for human capital policy in Canada are detailed. Each section, ends with a brief summary of the many points, and several key technical terms (highlighted in bold in the text) are defined in the Glossary of Terms.

2. Some Preliminaries

2.1 Measurement Issues

Productivity and Productivity Growth

Productivity typically refers to one of two concepts. Most of the literature discussed in this survey is concerned with *Labour Productivity* – measured real output per worker or per hour worked. Labour productivity is a "model-independent" measure and is close to a measure of average income. Labour productivity growth is then equal to growth in real output less the growth in the labour force (or total hours worked). Another important concept is *Total Factor Productivity* – real output per unit of a standardized function of inputs. Typically economists assume a Cobb-Douglas production function of physical capital and labour (and perhaps material inputs) given by

$$Y_t = A_t K_t^{\alpha} L_t^{\beta}$$

and refer to A_t as total factor productivity.[5] Here A_t represents technology, human capital and any other factor that raises the productivity of the inputs, including the dispersion of factor ownership. Although it is typically difficult to measure levels of capital, one can derive a measure of productivity growth using GDP growth, g_Y, net investment rates, g_K, and labour force growth, g_L:

$$g_A = g_Y - \alpha\, g_K - \beta\, g_L$$

An alternative measure of total factor productivity replaces labour with human capital as a basic factor input, where human capital is typically constructed from schooling data (e.g. Mankiw, Romer and Weil, 1992) and more recently schooling and experience (e.g. Bils and Klenow, 1999). In the latter case, A_t does not include the direct effects of human capital, although it may include indirect effects through the adoption of technology.

[5] The Cobb-Douglas relationship is consistent with the fact that factor shares have remained fairly stable over time in most OECD economies.

Inequality

Most empirical studies use an index of income inequality to proxy subsequent inequality in human capital or wealth. The most common measures are Gini coefficients and the income shares of the top 20% of the income distribution. The Gini coefficient is derived from the Lorenz curve of an income distribution which details the fraction of total income $z(p)$ received by the poorest fraction p of the population as p varies from 0 to 1. Perfect equality would be represented by a 45° line along which $z(p)=p$. The more bowed out is the Lorenz curve the higher is the degree of income inequality. The Gini coefficient is proportional to the area between the 45° line and the Lorenz curve and is therefore an index of overall inequality. Although the sources vary, the recent compilation by Deininger and Squire (1996) is probably the best current source. Typically, income distributions are thought to be much less skewed than distributions of wealth or human capital. Other studies have used inequality indices of land ownership arguing that, in less developed economies at least, these may be a better proxy for the true distribution of wealth.

2.2 Empirical Regularities

Before considering recent theories and evidence detailing the mechanisms through which inequality can affect productivity growth, it is useful to identify some broad stylized facts.[6]

Inequality and Productivity Levels

In a famous article, Kuznets (1955) hypothesized the existence of an inverted U-shaped relationship between per capita income and the extent of inequality. That is, inequality initially rises and then falls with per capita income. Kuznets suggested that this relationship could be attributed to the rural-urban wage gap and the migration of labourers from the countryside into the cities. Although his observations were based on a small number of cross-country and time-series data points, Kuznets' hypothesis became almost a "law" among development economists. Several articles have since confirmed the relationship in cross-country data (e.g. Paukert, 1973, Summers, Kravis and Heston, 1984) and for several developed economies (e.g. Williamson, 1985), but others have questioned the validity of Kuznets' hypothesis for individual less developed economies (e.g. Adelman and Morris, 1973). Fields and Jakubsen (1994) demonstrate that, although it seems to hold for a few developed economies there is in fact very little time-

[6] Some of the articles discussed in this section go further by attempting to establish the causal links. These attempts will be discussed further in the appropriate section.

series evidence to support Kuznets hypothesis. More recently, Barro (1999) finds that, although the Kuznets curve emerges as a clear empirical regularity in panel data, per capita income does not account for much of the variation in inequality across countries or over time.
A broad summary of the evidence to date is that the inverted U-shaped relationship appears to hold in cross-country data and, for several developed economies (i.e. those with a long enough data series) it holds over time. However, there is little evidence to support the hypothesis over time for individual less developed economies (see Li, Squire and Zou, 1998).

Inequality and Productivity Growth

Until very recently, most empirical research indicated a strong negative impact of inequality on subsequent growth in per capita income. Persson and Tabellini (1994) employ two different data sets, one with historical observations for 9 developed countries and one with post-war observations for 56 countries. Their results suggest that an increase of 0.07 (one standard deviation) in the share of income held by the top 20 percent of the population lowers average annual growth rates by just less than one half of one percent. Alesina and Rodrik (1994) employ different data for the period 1960-1985 from up to 70 countries. They report that an increase of one standard deviation for their Gini coefficient of land distribution would lower average per-capita growth rates by 0.8 percentage points per year. Both studies employ a similar methodology, obtaining a measure of inequality from at or near the beginning of a long sub-period of the data (Persson and Tabellini use 20 and 15 year sub-periods, Alesina and Rodrik use 1960-1985 and 1970-1985) and observing the influence of this measure on subsequent growth rates. Clarke (1995) and Perotti (1996) provide additional evidence on the robustness of this long run negative relationship to different measures of inequality and to different regression equation specifications.

Recently, Forbes (2000) has criticized the use of cross-country evidence in these studies. Using panel data for a cross-section of countries, Forbes finds a positive relationship between inequality and growth (she uses 5 year intervals). However, her methodology and results have come under significant criticism (see Aghion, Caroli and García-Peñalosa, 2000). In particular, her results are based on fixed-effects estimates, which have relatively few observations and are particularly sensitive to measurement-error problems. Also using panel data, Barro (1999) finds that the overall impact of inequality on growth over the subsequent decade to be weak, once one controls

for a broad set of other key determinants of growth.[7] The key difference in his results relative to those of previous authors who find a significant negative impact, appears to be the inclusion of a fertility rate variable. Once Barro drops this variable from his regressions, he gets similar results to Perotti (1996). Thus, the interpretation of these results depends on one's view of why fertility and income inequality are contemporaneously correlated.

A serious drawback of most of these empirical studies is their use of income inequality as a proxy for wealth inequality or human capital dispersion. Typically, income distributions are thought to be much less skewed than distributions of wealth or human capital. Moreover, the relationships between them vary considerably across countries, so that it is difficult to know how to interpret results based on cross-country growth regressions. Another important issue is the time frame over which the effects of inequality are expected to effect growth. The earlier cross-country studies tended to focus on the impact over longer time periods, whereas the more recent studies of Barro and Forbes use panel data and focus on shorter time periods.

Rising Returns to Skill and the Productivity Growth Slowdown

In the last quarter of the twentieth century a number of OECD countries (most notably the U.S. and the U.K.) experienced rising wage inequality. Although only a few countries experienced a significant rise in overall wage inequality, many experienced a significant increase in wage dispersion between particular skill groups.[8] Most commonly cited appears to be a rise in wage dispersion between education groups (e.g. Katz and Murphy, 1992) and between production and non-production workers in manufacturing (e.g. Berman, Bound and Machin 1999). Beach and Slotsve (1994), and Riddell (1995) find similar evidence for the Canadian situation. Morissette, Myles and Picot (1995) find that increases in earnings inequality in Canada are driven more by changes in hours worked than by wages. This may suggest a structural difference between Canadian and U.S. labour markets but is not inconsistent with the general view regarding an increase in relative demand for highly skilled workers. For Canada, Beach and Slotsve (1996) show that, although earnings inequality rose during the 1980's, income transfers substantially mitigated inequality increases in overall family income.

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[7] If anything, he finds a negative relationship for poorer countries and a positive relationship for richer ones.

[8] Juhn, Murphy and Pierce (1993) attribute about half of the U.S. increase to rising returns to unobservable skill components (i.e. within group inequality).

Coincident with the rise in returns to skill, most OECD economies experienced a slowdown in productivity growth. For example, Wolff (1996) finds that total factor productivity growth fell from an average rate of 1.61% between 1950 and 1973, to 0.47% from 1973-89, in the U.S. and from 1.05% to 0.56% in the U.K.. De Jong (1996) documents similar changes for Canada. Although there is a continuing debate over the true size and causes of this slowdown, it is tempting to hypothesize that the two phenomena are related in some way. Determining whether they are and understanding this relationship is important from a policy perspective since it suggests the possibility that by adopting appropriate policies a government might be able to improve performance on both counts.

2.3 Classical Views

The classical economists concentrated mainly on the division of output between the main factors of production. Although Adam Smith discussed the division of output into wages, rent and profit, it was Malthus and Ricardo who developed the first real theories of the determinants of the **functional distribution** of income. In their theories, long-run equilibrium is characterized by wages at a subsistence level and a profit rate just high enough to maintain the existing capital stock. Any short-run deviation of wages and profits away from this minimum level would cause the system to expand with capital accumulation pushing the economy back to its long-run equilibrium. Some of these ideas were incorporated into Marx's theories. In the Marxian analysis, capitalists extract surplus value and use this to accumulate capital and expand production. Workers are paid socially determined subsistence wages, which never rise permanently due to surplus labour that is continually replenished with workers displaced by mechanization. According to Marx, however, long-run profits would tend to fall, so that the system would eventually collapse.

Since the beginning of the twentieth century a very different view of the determinants of the functional distribution of income has come to the fore. According to the neoclassical model, all factors are paid according to the value of their marginal product. Pure production relationships and factor supply conditions determine their compensation and, hence, the distribution of income is part of the general pricing process. While the neoclassical model remains a dominant theory in macroeconomics, criticisms of it have led to several alternative theories of the functional distribution of income. Kalecki (1950), for example, argues that imperfect competition in output

markets would determine functional shares. The greater the degree of monopoly power, the greater the mark-up on variable costs and, hence, the lower the share of revenue going to labour. Neo-Keynesians disagreed with the emphasis of neo-classical theory on the allocative role of factor prices as signals to entrepreneurs. They treated investment as exogenously determined, or as a function of past profits. Kaldor (1956) argues that workers would have lower marginal propensities to save than capitalists. If investment increases, the increase in savings must come from a rise in the share of profits which in turn, determines the equilibrium functional distribution. The implied relationship between inequality and growth was therefore positive.

Income disparities in many economies are typically too large to be explained only by differences in factor endowments and, even where they are not, functional distribution theories do not tell us what causes these endowment differences in the first place. Moreover, these theories are not very useful for understanding the empirical regularities described in Section 2, or for providing a framework on which to base policy. As a result economists have developed a number of alternative theories of the **size distribution** of income and its implications for growth. It is to these various theories and the associated empirical evidence that I now turn.

3. Credit Rationing

3.1 What is Credit Rationing?

Credit rationing arises when, at the going rate of interest, there exist individuals who could profitably invest borrowed funds and repay with interest, but lenders are unwilling to lend to them in full. When this particular market failure arises it typically drives less wealthy, but potentially productive borrowers out of the loan market, leading to an inefficient allocation of resources, underinvestment and reduced productivity. One reason for rationing credit, may simply be that beyond a certain loan size, the benefits to the borrower from reneging on a loan become large relative to the penalties imposed by the lender to deter such actions (see Box 1).

Box 1

Perhaps the simplest example of credit rationing is that described by Sappington (1983). Suppose competition among lenders drives the interest on loans to *r*. Entrepreneurs can borrow some amount *L*, but they must put up their wealth (e.g. their house) b as collateral. After production they can abscond, losing *(1+r)b*, but escaping the repayment obligation, *(1+r)L*. If absconders are apprehended, which they are with probability p, they receive a penalty which imposes on them a cost d. Borrowers would renege if *(1+r)b+pd<(1+r)L*. Recognizing this, lenders will limit the size of their loans so that $L \# b + pd/(1+r)$.

Credit rationing may also arise in the presence of limited liability laws intended to encourage risk-taking by investors. Suppose the probability of a project's success depends on **non-contractible** actions taken by the borrower. Because of limited liability the borrower is effectively insured against downside risk and has an incentive to take actions which may involve excessive risk from the perspective of the lender. The lower the wealth of the borrower, and hence the larger is the loan, the bigger this "moral hazard" problem becomes. Hence, lenders may be unwilling to lend to those with wealth below some critical level.

3.2 Wealth Concentration in the Early Stages of Development

In the absence of well-functioning credit markets and when average wealth is low, inequality may enhance growth. This will be the case if there are investment projects, in particular the setting up of new industries during the early stages of development, that involve large sunk costs. In this context, wealth needs to be sufficiently concentrated in order for an individual to be able to cover such large sunk costs and thereby initiate new industrial activity. Even if there are

decreasing returns to wealth in production, when entrepreneurs face sunk costs, average net output will tend to exhibit **increasing returns** to wealth at low wealth levels. In such cases, redistribution of wealth towards a few wealthy individuals may raise productivity (see Box 2). Of course, an alternative approach is for such investments to be undertaken by a government that pools resources through taxation allowing for a "big push" towards further development.

Another kind of sunk cost that may arise in the early stages of development is the cost of setting up trading/financial relationships. Greenwood and Jovanovic (1990) study the dynamic interaction between "financial superstructure", inequality, and economic growth. In their model, market imperfections arise because it is costly to engage in financial intermediation which, through risk pooling, can allow entrepreneurs to earn a higher and safer return on their investments. If the higher returns available through financial intermediation justify the costs of forming such "syndicates", then these structures will tend to arise endogenously. The fixed cost associated with the formation of a financial intermediary structure ensures that the extent of financial intermediation, and thus the overall level of investment efficiency and growth, will be a function of the

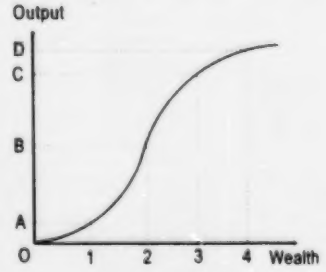
Box 2

Suppose the world consists of just two investors, Agatha and Bart, who have access to identical production opportunities illustrated by the stylized production function in Figure 1. This production function exhibits increasing returns to wealth at wealth levels below 2 units (due to fixed costs) and decreasing returns at wealth levels above 2 units (due to diminishing returns). Now suppose Agatha and Bart both have wealth equal to 1 unit, which could be invested in their own project or loaned (directly or via an intermediary). If Agatha loaned one unit of wealth to Bart, this would raise Bart's output by more than it would reduce Agatha's. It follows that there are "gains from trade": Bart is willing to pay a rate of interest on the loan that exceeds the opportunity cost to Agatha of taking it out of production.

If capital markets worked perfectly, Agatha would lend 1 unit of wealth and invest nothing, and Bart would borrow 1 unit of wealth and invest 2 units.* The final wealth of each individual would equal the income from production plus the return from net lending. Aggregate output would equal *OB*.

Suppose instead, capital markets are imperfect. Let's take the extreme example where there is zero lending. In this case, both Agatha and Bart would invest 1 unit in production. Aggregate output in this case is 2 x *OA* which is less than *OB*. If Agatha and Bart had started out with unequal wealth of 0 and 2, aggregate output would have been *OB*. Thus with increasing returns and capital market imperfections, more wealth inequality yields higher output. In contrast, inequality would have no impact on per capita output with perfect capital markets.

Figure 1: Returns to Scale and Inequality



* An alternative competitive outcome is that Bart lends to Agatha However, the aggregate implications would remain unchanged

distribution of wealth. In the early stages of development, growth is slow, but as wealthy investors organize, their investments are made more efficiently and they become proportionally more wealthy. Thus rising growth is associated with rising inequality. As incomes rise however, financial intermediation is more thoroughly exploited until income growth rates converge, and aggregate growth becomes independent of inequality.

3.3 Decreasing Returns and Credit Constraints

As Stiglitz (1969) first pointed out, when there are **decreasing returns** to capital and capital markets are imperfect, individual wealth need not converge to a common level and the aggregate level of output may be affected by its distribution (see Box 3).

Box 3

Let's return to Figure 1 and our two investor world. However, now suppose Agatha has an initial wealth of 4 which could be invested in her own project or loaned. Bart has initial wealth of 2, but could borrow to finance his investment. If Agatha loaned one unit of wealth to Bart, this would raise Bart's output by more than it would reduce Agatha's (*BC>CD*). It follows that there are "gains from trade": Bart is willing to pay a rate of interest on the loan that exceeds the opportunity cost to Agatha of taking it out of production.

If capital markets worked perfectly, Agatha would lend 1 unit of wealth and Bart would borrow 1 unit of wealth and each would invest 3 units. Aggregate output would equal twice the distance *OC*. If capital markets are imperfect, Agatha invests 4 units in production and Bart 2 units. Aggregate output in this case is *OB+OD*, which is less than 2 x *OC*. If Agatha and Bart had started out with the same initial wealth, the efficient level of output would have been attained with no trade. In the presence of market imperfections and diminishing returns to privately owned capital (physical or human), increased equality results in greater production efficiency.

Several recent theoretical analyses have built on this idea to study the interaction between economic development and the evolution of inequality in the presence of endogenous borrowing constraints and decreasing private returns to wealth. These analyses are typically carried out in overlapping generations (OLG) models with intergenerational altruism. These are dynamic models which capture the fact that an individuals lifetime is finite, causing them to behave differently than would an infinitely-lived representative household. In the simplest version, individual lifetimes are divided into two periods: young and old. The young make investment decisions (e.g. education) which determine their incomes when old. The old care in some economically meaningful way about their offspring and provide complementary inputs and are taxed to finance public expenditures. In some cases this might imply that parent's care about their childrens' utility as if it

was their own. Many of the models discussed below assume (for simplicity) that parents derive utility from the size of the bequest or the quality of education they leave for their children.[9]

Suppose that individuals inherit heterogeneous levels of wealth and must decide whether to invest in a fixed and indivisible level of human capital. Credit market imperfections result in the lending rate on capital being lower than the borrowing rate (due to monitoring costs). Thus, education is limited to those with sufficient wealth to purchase it outright or to pay a high rate of interest on loans. These individuals become skilled workers and those without an education are unskilled. In an OLG model, Galor and Zeira (1993) show that, as a result of this mechanism, the initial distribution of wealth determines the aggregate amount of human capital investment and long-run per capita income. If initial inequality is sufficiently low, an egalitarian steady-state arises where all workers receive the same high-skilled wage and per capita income reaches a maximum. Otherwise, a low level one emerges where a fraction of the work force earns disproportionately low wages. Banerjee and Newman (1993) also show the potential for long-run outcomes to be determined by initial levels of inequality, providing examples in which the economy either prospers or stagnates depending upon initial distributions of wealth.

In Aghion and Bolton (1997) agents either invest in a fixed-size, risky project, lending any remaining wealth or borrowing if necessary; or they earn a safe, low income and lend. Limited liability and the dependence of the success probability on non-contractible effort induces credit-rationing based on inherited wealth. Equilibrium between borrowers and lenders determines a market interest rate which varies with the distribution of wealth. As wealth accumulates, demand for credit declines and supply rises, so that interest rates fall and, although it may initially rise, wealth inequality eventually falls. An important feature of their model is that the presence of idiosyncratic shocks to income implies that over time, even the wealthiest lineage could eventually become poor and the poorest lineage could become rich. This "ergodicity" implies that the initial distribution of wealth does not affect either the degree of inequality or per capita income in the long run. It follows that any positive effects of redistribution do not persist, so that perpetual redistribution is always necessary to achieve the maximum per capita income.

[9] To the extent that the preferences of parents and their children differ, this may actually be a more sensible representation.

Lloyd-Ellis and Bernhardt (2000) develop a more general model than Banerjee and Newman in which individuals differ in their entrepreneurial efficiencies as well as their inherited wealth levels. They characterize the entire evolution of the distributions of wealth and income from a low level state to an advanced economy and study its interaction with the development process. The impacts of wealth and ability are distinct and vary as the economy develops. While in initial stages, wealth is the primary determinant of occupation because wealthy agents can invest in capital and profitably exploit cheap labour on a grander scale; in later stages, entrepreneurial efficiency matters more both because fewer agents are wealth constrained and because higher wages reduce the profitability of large scale production. The consequence for the dynamics of income and wealth inequality is that they first rise and persist along family lineages, and then fall and are less persistent along lineages. That is, a Kuznet's curve arises endogenously and social mobility increases over time.

One problem with all of these models is that they assume that individual's simply inherit their wealth so that, for example, redistribution does not affect incentives. Ghatak, Morelli and Sjöstrom (1997) develop an alternative model in which individual's must first work and save before they can acquire enough wealth to invest in their own enterprise. Their wages depend on their own effort and the existence of a credit constraint generates incentives to work harder (they call this the "American Dream" effect). In their model, redistribution (via income taxation, say) can destroy these incentives and will tend to offset the productivity gains from redistribution arising from decreasing returns to wealth in production. Hence, a trade-off arises between the short-run costs and long-run gains of redistribution.

3.4 Evidence on Credit Constraints

Financial constraints have been found to play a crucial role in the entrepreneurial process in both developed and less developed countries. Evans and Jovanovic (1989) and Holtz-Eakin, Joulfaian and Rosen (1994), for example, find that capital is essential for starting a business in the U.S. and that borrowing constraints tend to exclude those with insufficient funds at their disposal. Similarly, Blanchflower and Oswald (1998) find that those individuals who inherit significant amounts of wealth are much more likely to start a business in the U.K.. Given that these two economies have the most developed capital markets, borrowing constraints are likely to be even

more prevalent in other countries. In particular, Levy (1993) and Fidler and Webster (1996) find considerable evidence that entrepreneurs in LDCs are borrowing constrained.

The evidence that short-run credit constraints are important for private human capital investment is far less clear, especially for developed economies. It is well-documented that children from low-income families complete fewer years of schooling than other individuals, despite high rates of return to schooling (see Jimenez, 1986 and Kane, 1994). However, it is not clear that this is because they do not have sufficient access to credit to pay for higher education. For example, Cameron and Heckman (1998) find that after they account for other background characteristics and scores on ability tests, measured family income plays only a minor role in explaining schooling attainment in the U.S.. Heckman and Klenow (1997) argue that "Long term factors, like ability, family structure, neighbourhood effects and the quality of the primary and secondary schools an individual attends may be more important than short term credit constraints in determining who goes to college."

Note, however, that this does not imply that family income is unimportant for schooling attainment. Family income affects the kind of community that children grow up in, the schools they attend and important complementary inputs to human capital formation such as nutrition, location, books, family holidays, etc. All of these factors in turn affect how well they do early on in the schooling system (and hence their performance on tests), which determines the feasibility and optimality of continuing on to higher levels of education and training. Thus, while short-term credit constraints on attending college or university may not play a pivotal role in human capital investment, there is a crucial *long-term credit constraint*: poor parents cannot borrow against their children's anticipated earnings in order to finance key complementary inputs to their child's human capital. Social programs and income assistance programs targeted at poor households with young children counteract this long-term credit constraint and thereby help to improve the environments that shape ability and preparedness for learning.

Summary

- With credit constraints on investment in physical or human capital, the impact of wealth inequality depends on the **returns to scale** faced by the investor. With **increasing returns** to wealth due to fixed costs, greater wealth inequality may enhance investment and per capita output. With **decreasing returns** to wealth, greater wealth inequality will reduce per capita output.

- It seems likely that private agents face increasing returns at very low wealth levels and decreasing returns at high wealth levels. It follows that inequality will tend to have a positive impact on per capita output at very low wealth levels and a negative impact at high wealth levels. Moreover, under these conditions a Kuznets Curve will tend to arise endogenously as the economy develops.

- Empirical evidence on short-run credit constraints in advanced economies suggest that they are important for investment in physical capital by entrepreneurs, but less so for investments in human capital. However, long-run "intergenerational" borrowing constraints are important determinants of human capital investment.

4. Static Externalities: Human Capital Spillovers in Production

4.1 Human Capital as an Engine of Endogenously Sustainable Growth

Although the importance of human capital in determining aggregate productivity has long been recognized,[10] its role as an engine of endogenously sustainable growth became part of mainstream macroeconomic thinking following the work of Lucas (1988). In his formulation of the problem, output is a function of physical capital and human capital devoted to production. Increments to human capital are a function of the fraction of the current stock of human capital devoted to learning (e.g. education and job training). The technologies for production and human capital accumulation both feature constant returns to scale. In the Lucas framework, productive knowledge is embodied in workers' skills that are, in turn accumulated through *endogenous*, utility-maximizing investment decisions (schooling, training, and learning-by-doing) that sacrifice present consumption in order to raise future productivity and income. The constant returns assumption is crucial. If investments were subject to diminishing returns then sustained growth along a **balanced growth path** would be impossible.

In the basic Lucas framework, human capital investment decisions involve no distortions, and there are no externalities, so human capital accumulates at the socially efficient rate. Economic growth is efficient and there is no role for government intervention in the process. However, this conclusion is an artifact of the production technology in which human capital produces no externalities. Yet the fact that education is almost always publicly financed, and to a large degree, suggests that individual decisions to acquire human capital create external benefits for others. Lucas (1988) therefore analyzes an extension of his model in which the output of each firm depends on the human capital of its own workers as well as the average value of human capital per worker in the economy – a *static production externality* (see Box 4). With this technology, decentralized decision-making yields too little investment in human capital, as individual decisions to invest do not take into account the productivity gains from that investment which are realized by others. Steady state output is too low relative to the social optimum, and growth is too slow.

[10] See T. W. Shultz (1961), for example.

Box 4

In Lucas' basic framework, output, $Y(t)$, and the rate of change of individual human capital, $\dot{h}$, are given by

$$Y(t) = (t)^{\sigma}(uNh(t))^{1-\alpha} \quad (1)$$

$$\dot{h} = Bh(t)(1-u) \quad (2)$$

where $K(t)$ denotes physical capital, $h(t)$ denotes human capital, N denotes the size of the working population, u denotes the proportion of labour time devoted to production and A, B and α are technology parameters. With constant returns to scale in both (1) and (2), the marginal product of human capital is constant. As a result all individuals allocate equal effort to accumulation and their human capital grows at the same constant rate. In Lucas' extension, he retains (2) but replaces (1) with

$$Y(t) = AK(t)^{\alpha}(uNh(t))^{1-\alpha-\gamma}H(t)^{\gamma} \quad (3)$$

Here, the term $H(t)$ represents an external effect of average human capital on production – an effect which is not taken into account by individuals when making there investment decisions. This externality leads to underinvestment in human capital. Moreover, although (3) still exhibits constant returns overall, it also implies that individuals face diminishing returns in their private investment decisions. By using a representative agent framework, Lucas effectively assumes perfect tradeability of human capital, so in his case the distribution of human capital is of no consequence.

4.2 Static Human Capital Expenditures

The existence of a static externality in production like that studied by Lucas (1988) opens the door for the dispersion of human capital to impact upon productivity and productivity growth. The existence of a positive externality coupled with the necessity for there to be constant returns to overall human capital accumulation, implies that there must be diminishing returns to individual human capital accumulation. For heterogeneity in human capital to not affect the growth rate would require that embodied human capital is a perfectly tradeable input to production. While it is possible to think of quasi-examples of people trading pieces of their human capital (e.g. specialized consulting services), it is often difficult to imagine someone selling analytical power to one firm and creative power to another at the same time in two different cities. In general, such markets are likely to be thin or non-existent.

Benabou (1996) illustrates how a static human capital externality in production can arise when workers with different skills are complements in production (see Box 5). The complementarity is supposed to capture the idea that "... poorly educated, insufficiently skilled production or clerical workers will drag down the productivity of engineers, managers, doctors and so on. Conversely, lagging advances in knowledge by scientists, engineers and other professionals will mean lagging wages for basic workers." In Benabou's production set up, this complementarity implies that an

individual worker's wages depend positively on the current average level and equality of human capital in the economy, as well as his/her own schooling. Moreover, aggregate productivity is a decreasing function of the dispersion of human capital. Because household investments in human capital accumulation is subject to idiosyncratic shocks, inequality persists over time and creates a drag on long-run productivity growth.

An alternative microfoundation to explain why average human capital might impact upon individual productivity is considered by Acemoglu (1996). Suppose there are two periods. In the first, firms make irreversible investments in physical capital and households invest in human capital. Workers and firms come together in the second period. The labour market is not competitive: instead, firms and workers are matched randomly. The only decision workers and firms make after matching is whether to produce together or not to produce at all. Firms base their investment decisions on the expected human capital of the workers they hire. Thus, although a worker's wages will depend on his/her own human capital, it will also depend positively on average human capital via the investment decision. With decreasing returns to individual human capital in production, returns also depend negatively on the variance of human capital.

Box 5

Benabou (1996) assumes that final output is produced according to a CES technology using intermediate inputs supplied by monopolistically competitive firms. He supposes that workers must specialize in single input and allocates a constant fraction, ν, of labour time to production. As a result aggregate output is given by

$$Y_t = u\left(\int_0^{\infty} h\alpha \, d\mu_t(h)\right)^{\frac{1}{\alpha}} = uH_t \qquad (4)$$

where $\mu_t(\cdot)$ denotes the distribution of human capital. This reduced-form production function features symmetric complementarity between workers of different skills. The implied wage received by a worker with human capital h is equal to its marginal product and is given by

$$w_t(h) = H_t^{1-\alpha} h^{\alpha} \qquad (5)$$

Here the external effect, H_t, depends on both the mean and variance of the distribution of human capital. In particular, if the distribution of skills is log normal with mean m_t and variance σ_t, the externality is given by

$$H_t = \exp\left(m_t - (1-\alpha)\frac{\sigma_t}{2}\right) \qquad (6)$$

4.3 Evidence on Static Human Capital Externalities

A key implication of this link between inequality and productivity is that, controlling for own human capital (i.e. schooling and experience), the productivity (i.e. the wage) of an individual worker is higher the higher is the human capital of other workers in the economy. On balance,

recent evidence offers little support for sizeable social returns to education operating through a *static* externality in production.

One approach to measuring the social returns to schooling is to compare the aggregate output effect of schooling across countries with the individual micro returns. Early studies (e.g. Barro and Sala-i-Martin, 1995) find that across countries, each additional year of average schooling is associated with about 30% higher GDP per capita. In contrast, across individuals within a country, each additional year of schooling is associated with roughly 7-10% higher wages (Psacharopoulos, 1994). This large discrepancy between macro and micro rates of return has been interpreted by many as evidence that there exist huge positive externalities to schooling. However, as several recent studies (e.g. Bils and Klenow, 1999, Heckman and Klenow, 1997 and Howitt, 2000) point out, the macro estimates attribute too large an output effect to schooling. Causality may run from technology to income/life-span, or from future anticipated growth to schooling. When Heckman and Klenow (1997) include life expectancy in the macro regression to proxy for cross country differences in technology, the average schooling coefficient falls to about 10\%, which is in the same ball park as the micro estimates. Similarly, Bils and Klenow (1999) find that only a fraction of the correlation between schooling and per capita GDP growth, estimated by Barro and Sala-i-Martin (1995), comes from the impact of schooling on GDP growth. The remainder appears to be a result of reverse causation – the anticipation of future growth induces greater investment in human capital. This is because the benefit to having human capital is proportional to aggregate productivity while working, whereas the opportunity cost is proportional to aggregate productivity while in school. Thus, higher productivity in the future relative to today, which is to say higher productivity growth, raises the private returns to investing in schooling.

Another approach is to include a measure of average schooling in a given area in regressions of individuals wages on their own schooling and other characteristics. Using data from U.S. Standard Metropolitan Areas (SMSAs), Rauch (1993) finds that controlling for a worker's own education and experience levels, the worker's wages are higher the higher the average level of education in the worker's SMSA. Rauch finds that a worker's wages are 3.1% higher for each additional year of SMSA average education. Maré (1995), Peri (1998) and Moretti (1999) also estimate the effect of average schooling in U.S. cities on individual wages, while Acemoglu and

Angrist (2000) estimate the effect across U.S. states. A key problem in estimating the returns to both own and average schooling is the potential endogeneity of schooling to wages. In order to avoid upward bias in their estimates, researchers must identify an exogenous source of variation in schooling (a "natural experiment") and use that to estimate the relevant coefficient. Moretti (1999) instruments for average schooling with changes in city age structure, tuition costs and the presence of a land-grant college, but treats individual schooling as exogenous. He finds that the social returns to schooling exceed the private returns. Acemoglu and Angrist (2000) identify sources of exogenous variation for both own schooling (birth quarter) and average schooling (compulsory schooling laws). They find that workers' wages are typically less than 1% higher for each additional year of state average education.

Summary

- The existence of a static human capital production externality in an endogenous growth model, together with non-tradeability of private human capital, implies that inequality of human capital will affect the growth rate.

- Along a balanced growth path, the existence of a positive externality implies that investments in private human capital must exhibit diminishing returns. It follows that initial human capital inequality will have a negative impact on long-run growth.

- Empirical evidence on the existence of *static* human capital externalities is mixed. Early estimates found them to be potentially very large. However, more recent studies that attempt to avoid endogeneity problems in estimation, suggest that such externalities are small.

5. Dynamic Externalities: The Role of Education and Training

5.1 Short-Run Dynamic Externalities

An alternative externality to that considered by Lucas (1988) would be one whereby individuals *learn more*, the higher is the human capital of others in the (local) economy. This alternative is considered by Tamura (1991), who retains the aggregate production function hypothesized by Lucas (1988), but supposes that the individual's human capital accumulation technology features an aggregate spillover. This *dynamic externality* implies that controlling for own schooling, the greater is the average stock of human capital in the economy the larger will be the *increments* to an individual's productivity. Because there are decreasing returns to individual human capital and because Tamura assumes that human capital is non-tradeable, the human capital inequality has a negative effect on the average growth of human capital. If an agent's level of human capital is above average, then the marginal return to investment in human capital is lower than if it were below average. It follows that if one were to transfer a unit of initial human capital from someone with high human capital to one with low human capital, the increase in productivity growth experienced by the low human capital agent would exceed the reduction in productivity growth experienced by the high human capital agent.[11] Moreover, since someone with a relatively high initial human capital stock accumulates further human capital less rapidly than one with a lower initial stock, their incomes will eventually converge (see Box 6).

Box 6

Tamura (1991) effectively maintains Lucas' (1988) basic production technology, but replaces (2), with

$$\dot{h} = BH(t)^{\gamma}((1-u)h(t))^{1-\gamma} \qquad (7)$$

where $H(t)$ denotes the external affect of average human capital in the accumulation process. He also assumes that human capital is non-tradeable. Although, there are constant returns overall, individuals face decreasing returns to private investment in human capital. Rearranging (7), we can write an individual's human capital growth rate as

$$\frac{\dot{h}}{h} = B(1-u)^{1-\gamma}\left(\frac{H}{h}\right)^{\gamma}. \qquad (8)$$

Thus, the growth rate of human capital is higher than average for an individual with $h<H$ and lower than average for an individual with $h>H$.

Unlike Lucas (1988), Tamura's model does not predict that an individual's wage will be higher, the more the human capital of other contemporaneous workers, but rather that his wage will grow faster. An alternative, longer run interpretation of Tamura's model would be that, controlling for own schooling, a

[11] Note that since the human capital production function exhibits constant returns to all factors, sustained growth is possible.

workers wages should be higher, the higher was the average human capital of those around at the time of schooling and training. Although Tamura's model is suggestive, it is rather stylized and does not provide an explicit account of how or why average human capital impacts upon the individual learning process. Recently, however, several authors have developed alternative theories which explicitly model the way in which such dynamic externalities operate and which provide specific implications for policy. In particular, one way in which dynamic externalities may arise is through the public education system. If the stock of human capital in the (local) economy is high, the tax base will also be high, allowing for greater expenditures on and, consequently, higher quality of public education.

5.2 Private versus Public Education

In an overlapping generations model, Glomm and Ravikumar (1992) illustrate the role of formal education in determining the interactions between growth and inequality.[12] Parents care about the quality of their children's education which, in conjunction with their own level of human capital, determines the human-capital acquisition by their child. The authors compare the economy's growth path and the evolution of the distribution of income under private and public mechanisms for the provision of education. With private provision, the quality of a child's education is determined by his/her parent's income. As a result the child's human capital is a function only of his/her parent's human capital, so that inequality persists. In contrast, under a public education regime all students receive an equal quality of education determined by average income. Since the private marginal returns to parental human-capital are diminishing, inequality declines relatively rapidly over time. Since, under private provision, all returns are appropriated by the individual, more effort is allocated to schooling than under public provision, so that the growth rate tend to be higher, for a given degree of inequality. However, if initial inequality is sufficiently high, growth under public provision of education will eventually surpass that under private provision, because of the faster reduction in inequality.

If one introduces **idiosyncratic shocks** to income (due to differences in innate ability, say) into the Glomm and Ravikumar model, it turns out that public provision always leads to higher long-run growth, because inequality persists. One implication of this kind of model is that economies

with more emphasis on public education systems should exhibit more social mobility than those with less. However, when comparing Italy and the U.S., Checchi, Ichino and Rustichini (1999) find that Italy, while displaying less income inequality, also displays less intergenerational upward mobility between occupations and between education levels. They argue that when family background is important for labour market success, an overly centralized and egalitarian tertiary education system need not help poor children and may take away from them a fundamental tool to prove their talent and to compete with rich children. In contrast, at the primary and secondary levels the quality of schools matters more than individual effort, so that a state-run school system generates larger human capital investment by poor families.

5.3 Local Externalities

Rather than thinking of dynamic human capital externalities as being economy-wide, it is often more useful to think of them as being local in nature. For example, in the U.S. the financing of public primary and secondary schools has a large local component and thus is a function of community income (via taxation).[13] If households cannot borrow against the future earnings of their children to finance current expenditures, inefficiently low investment in human capital among children from poor neighbourhoods may result. Alternatively, such externalities may be social, arising from the interaction of the aspirations and performance of students in affluent and less affluent neighbourhoods. In either case, there is a tendency for stratification to imply self-replicating neighbourhoods, and the segregation of the poor (see Durlauf 1994).

Benabou (1996) analyzes the effect of schooling on growth when students of heterogenous abilities can either be segregated or mixed together.[14] In the short run, segregation may increase growth because talented people are complements in producing new human capital. In the long run however, segregation leaves intact the overall heterogeneity of skills in the economy,

[12] Given the long run nature of dynamic externalities operating through the education system, overlapping generations models seem like a reasonable framework within which to think about these issues.

[13] A larger portion of the funding of Canadian schools is at the provincial level, but there are still significant disparities within provinces. Moreover, the local environment is still an important factor in determining schooling outcomes.

[14] Benabou's model actually features *both* static and dynamic externalities. In his model, the impact of human capital inequality arises through a static externality due to the complementarity in aggregate productivity. However, this need not be so – one can also introduce it in the human capital accumulation process and obtain the same qualitative results (see Love and Lloyd-Ellis, 1997).

perpetuating inequality in the long run, and creating a drag on productivity growth. This has implications for school finance. If schools are financed locally, in communities that are sorted on talent or resources, then expenditures on education will tend to perpetuate inequality and reduce long run growth. Greater funding equality (through centralized taxation) and reduced segregation on talent leads to lower long run inequality and higher growth. In this model, centralized financing and a national curriculum may provide a long run advantage relative to a decentralized system.

Over the last two decades several U.S. states introduced legislation which effectively increased their role in the provision of education relative to local districts, effectively equalizing expenditures per student across districts. Murray, Evans and Schwab (1998) find that court-ordered finance reforms between 1971 and 1996 reduced within-state inequality in spending by 19 to 34%. Fernandez and Rogerson (1998) examine the consequences of such reforms in the context of a dynamic equilibrium model of public-education provision, calibrated using U.S. data. They find that the policy increases both average income and the share of income spent on education, and significantly increases welfare.

5.4 Public Expenditures across Levels of Schooling

What are the likely impacts of alternative allocations of public resources between basic and higher levels of education on enrolments, income distributions and growth? In Lloyd-Ellis (2000), basic education is compulsory, but increments to higher education are voluntary. Parental incomes affect their children's human capital accumulation (e.g. nutrition, books, family holidays, etc.), but there are decreasing returns to this input to human capital. There are two types of occupation: in high-skilled jobs, workers can fully appropriate the returns to their education, but in low-skilled jobs they cannot. Since the acquisition of higher education is costly, students who anticipate employment in low-skilled occupations have little incentive to acquire education beyond basic levels. As a result, the distribution of income among parents and the relative quality of different education levels affects the incentives of students to acquire higher education. The growth impacts of the allocation of public resources between basic and higher education reflects a trade-off between the "trickle-down effects" of high quality higher education and the positive growth effects of increased enrollments and reduced parental inequality. If resources are overly skewed towards higher education and away from basic education, this reduces the incentives of

marginal students to acquire higher education and increases inequality. Both factors have a negative impact on growth. However, the benefits of "levelling the playing field" by skewing resources towards basic education are eventually offset by the costs resulting from the reduced productivity of high-skilled workers.

5.5 The Evidence on Dynamic Human Capital Externalities

The short-run version of this dynamic externality implies that, controlling for individual characteristics, increments to an individual's productivity should be greater, the greater is the average level of human capital. There is some evidence for such short-run dynamic externalities. For example, Borjas (1995) finds that migrants who move to locales with higher than average human capital enjoy faster wage gains from the date of entry into the U.S. than those who move to other locales.

In the longer run models discussed above, the human capital acquired by each generation depends on parental inputs (income and/or human capital) and public education expenditures financed by taxing the previous generation. As a result average investments in human capital (and therefore wages) are increasing in the mean and equality of the human capital of the *previous* generation. Williamson (1993) and Lloyd-Ellis (2000) provide cross-country evidence suggesting that greater parental inequality is indeed associated with lower secondary school enrollment (controlling for per capita income). Another piece of supportive evidence is that the quality of schools attended by workers certainly seems to matter for their wages later in life and that the quality of schools is a function of local human capital. For example, Card and Krueger (1992) find that American men who were educated in states with higher-quality schools (measured by pupil teacher ratios, average term length and relative teacher pay) have a higher rate of return to additional years of schooling. Rates of return are also higher for individuals from states with better-educated teachers. Indeed, Hanushek (1992) finds that "the difference in student performance in a single academic year from having a good as opposed to a bad teacher can be more than one full year of standardized achievement." While this empirical evidence is consistent with the potential importance of dynamic externalities, it does not prove their existence. Overall, this seems to be an area where there is still much empirical work to be done.

Summary

- An externality in the human capital accumulation process itself also implies that, along a balanced growth path, investments in private human capital exhibit diminishing returns, so that (assuming non-tradeability) human capital inequality will have a negative impact on productivity growth.

- In the long-run, such dynamic externalities can arise via the public education system itself. Greater expenditures on public education will tend to reduce the sensitivity of a child's educational outcomes to his/her parent's income/human capital. This can help to raise average human capital investments and reduce the persistence of inequality through time.

- The exact nature of these effects and their implications for public policy depend crucially on the structure of the education system and social interactions – the importance of private versus public inputs, the importance of local versus economy-wide externalities, and the balance of spending across primary, secondary and tertiary levels of education.

6. Technological Change and Skills

6.1 Technological Change as an Engine of Endogenously Sustainable Growth

In a seminal paper, Romer (1990) develops an alternative paradigm of endogenously sustainable growth – one based on the accumulation of **disembodied knowledge** in the form of new technologies and ideas. In his model, as in Lucas (1988), output is a function of physical capital and the portion of human capital devoted to production. However, physical capital is made up of heterogeneous intermediate inputs, whose overall productivity is a function of the state of applied knowledge. Increments to knowledge are a function of past knowledge and the labour effort devoted to research and development. The incentives to invest in R&D come from the monopoly profits from new innovations which are protected, at least temporarily, by patents. Although the technologies themselves cannot be used by others, the knowledge generated by R&D is "non-rival" and feeds into future innovations, thereby making growth endogenously sustainable. Thus, in contrast to the Lucas model, positive externalities are an inherent part of a growth process driven by disembodied knowledge accumulation. Because investors do not take into account the positive effects of their R&D on future innovations, economic growth is inefficiently low and there is a role for government intervention in the process (e.g. by subsidizing R&D or strengthening intellectual property rights).

Grossman and Helpman (1991) and Aghion and Howitt (1992) develop somewhat different models of growth through disembodied technological change. However, the main implications of their work are similar to those of Romer. These models have little to say about the distribution of wages because they presume that neither the development nor the implementation of new ideas and technologies require greater skill levels to implement them. As a result, relative wages are independent of the rate at which new technologies are introduced. However, the recent rise in returns to skill discussed in Section 2 has led to increased interest in the possibility that technological change may often (or even generally) be skill-biased.

6.2 Skill-Biased Technological Change

Alternative hypotheses for the rise in returns to skill since the mid-1970s are that it stems from government policies, changes in the global economy, specifically increased international competition (Wood, 1994), or skill-biased technological change. Murphy and Welch (1993) argue that the rise in returns to skill appears to have progressed in a smooth fashion for a relatively long time in the U.S. and thus that it is unlikely that they are a short-run consequence of governmental policies. Moreover, the fact that the rise in returns to skill seems to be global in nature suggests that government policy shifts are not the main cause. A consensus is also emerging that trade effects can at best explain a small portion of the changes (see Berman, Bound and Machin, 1998 and Wood, 1998).[15] Thus, the leading hypothesis appears to be that the rise in skill-premia is associated with the skill-bias of newly introduced technologies.[16]

The skill-biased technical change hypothesis is supported by estimates of equations relating the employment share of non-manual workers to R&D expenditures and computer use. Berman, Bound and Griliches (1994) show that both computers (as a share of total investment in 1974) and R&D expenditures have a positive and significant impact on the increase in the share of **non-production workers** in the total wage bill: these two factors account for 70\% of the move away from **production labour**. Autor, Katz and Krueger (1997) find similar results in U.S. non-manufacturing, and Machin and Van Reenen (1998) confirm the empirical regularity for a number of OECD countries. Overall the empirical evidence indicates that more technologically advanced industries are more likely to have increased their relative use of skilled workers.

One puzzle regarding the exogenous, skill-biased technological change hypothesis is that the rise in the relative returns to skill since the mid-1970s coincided with the decline in the rate of productivity growth in most OECD countries. As Blackburn, Bloom and Freeman (1991) put it "U.S. productivity during the 1980s showed only sluggish growth, not the rapid advance one might expect if technological change were the chief cause of the changing structure of wages".

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[15] The case against the importance of international trade is really a case against the importance of trade in final goods. It is possible that changes in the trade of intermediate goods associated with out-sourcing is a major source of rising skill-premia (see Aghion, Caroli and García-Peñalosa, 2000).

[16] Beaudry and Green (1997) find no evidence of increased within-cohort dispersion of earnings in Canada. Rather they document that much of the increase in Canadian wage dispersion is due to a deterioration in the wages of more recent cohorts.

The slowdown in productivity growth was reflected in the stagnation of average real wages. The existence of such a slowdown raises questions about the validity of a hypothesis that attributes the increase in wage differentials to an acceleration of technological progress.

Proponents of the exogenous, skill-biased technological change hypothesis have addressed this puzzle by offering reasons why an increase in the rate of technological change might initially result in a downturn, followed by an eventual upturn in productivity growth. Hornstein and Krusell (1996) provide evidence that there was an increase in the rate of technological change embodied in capital during the mid-1970s which they argue caused a temporary slowdown as resources were shifted towards some unmeasured learning activity. Krusell, Ohanian, Rios-Rull and Violante (1997) estimate that the degree of complementarity between skilled labour and capital equipment in the U.S. would have been sufficient for this increase in investment-specific technical change to have generated much of the observed increase in returns to education. Greenwood and Yorukoglu (1997) illustrate that when the unobserved learning activity requires skilled labour, the increased rate of investment-specific technological change might account for both aspects of the data. Similar arguments have been made by Aghion and Howitt (1998) and Galor and Tsiddon (1997), in the context of the introduction and dissemination of **General Purpose Technologies**.

6.3 Endogenous Innovation, Productivity Growth and the Distribution of Skills

An alternative approach is to follow Romer (1990) in assuming that innovation responds endogenously to incentives. In such cases, the nature or the rate of innovation may be affected by the distribution of skills in the economy. For example, Acemoglu (1998) argues that if the nature of innovations depends upon the distribution of skills, changes in the distribution of skills may have effects on the skill-bias of new technologies, without affecting the rate of productivity growth. He supposes that researchers target their effort to innovations that complement either skilled or unskilled labour. Since research is a fixed cost, the returns to R&D depend on the number of workers that will be able to use the new technology. For as long as the number of skilled workers was small, R&D targeted products that were complementary with unskilled workers and hence technical change reduced the skill premium. The expansion of education since the 1960s made it profitable to invent machinery to be used by skilled rather than unskilled

workers. Technical change *became* skill-biased and the ratio of skilled workers' wages to unskilled workers' wages increased even with no change in the aggregate rate of productivity growth.

One problem with this argument is that a growing body of evidence suggests that skill-biased technological change in the 1970s and 1980s continued a trend that has proceeded for most of the twentieth century, and perhaps further back than that. Berman, Bound and Griliches (1994) find it is present in U.S. manufacturing dating back to the late 1950s. Goldin and Katz (1996, 1998) document the role of electrification and new production methods (e.g. batch processing) in increasing the demand for non-production workers in manufacturing in the 1910s and 1920s. The skill premium has declined when supply outstripped demand (in the early 1900s and again in the 1970s) and has increased when the supply of educated workers did not keep pace with demand.

An alternative hypothesis that explicitly links the rise in wage inequality with the slowdown in U.S. productivity growth is explored by Lloyd-Ellis (1999). In his model minimum skill levels are required to implement new ideas and technologies. Workers are distinguished by the range of ideas and technologies that they are capable of implementing and it takes time to acquire the necessary skills. In the short-run, if new technologies are introduced into the economy more rapidly than most workers can learn to implement them, the wages of those who learn fastest will rise. This, in turn, drives up the relative cost of R&D, which uses the most skilled workers, causing the rate of innovation to decline. It follows that rising inequality may be associated contemporaneously with *declining* growth rates of productivity and average real wages. The size of the increase in wage inequality depends crucially on the underlying dispersion of skills.

The existence of endogenous skill-biased technological change provides another mechanism through which the distribution of skills may impact upon productivity growth. If appropriately skilled workers are scarce relative to less skilled workers, this may result in an allocation of resources towards current production and away from the introduction and implementation of new technologies, to the detriment of long run productivity growth. However, for such a situation to persist for so long implies that there must be some reason why individuals are unable or are not choosing to acquire the necessary skills, despite the apparent high returns to doing so. There are several possible explanations: public institutions are not offering an appropriate match between

skills and technology, there are borrowing constraints (see Section 4) or there is underinvestment due to some kind of externality.

6.4 Evidence on the Impact of Human Capital Inequality on Innovation

The evidence regarding the impact that the distribution of human capital may have on the rate of innovation and implementation is fairly thin on the ground. In a study of the adoption of Green Revolution technologies in India, Foster and Rosenzweig (1996) find that, controlling for own-education, a farmer is more likely to adopt a new seed technology after it has been used by a neighbour. Across countries, the rate of introduction of new technologies, as measured by the growth in patenting, does decline with the extent of inequality (controlling for per capita GDP growth). However, it is not clear what this implies because poorer countries tend to adopt foreign technologies without patenting. Once again this seems to be an area where there is considerable room for further empirical research.

Summary

- The recent rise in returns to skill in many countries has been attributed by many economists to skill-biased technological change. However, there is growing evidence that most major technological changes this century have been skill-biased.
- If technological change is endogenous, then the fact that it is skill-biased provides another avenue through which the distribution of human capital may affect the rate of productivity growth.
- The empirical evidence regarding the significance of this mechanism is at an early stage.

7. Other Mechanisms

7.1 Political Economy: Endogenous Redistribution

Another strand of the positive theoretical literature on growth focuses on the relationship between inequality, the political process, and government policy. In this literature political outcomes determining government policy are endogenous to the distribution of wealth or income in the economy. Rational economic agents vote for or against tax policies which have redistributive consequences. Greater inequality (i.e. a poorer median voter) tends to result in higher equilibrium tax rates since a larger proportion of voters will favor redistributive policies. In Bertola (1991), Alesina and Rodrik (1994), and Persson and Tabellini (1992, 1994) redistributive policies of this sort reduce the private, after-tax marginal product of capital and create a disincentive to investment that leads to lower growth. These models thus predict that inequality and growth will be indirectly negatively related through the political process.

Perotti (1993) examines political mechanisms similar to those just mentioned except in a model where growth is driven by human capital accumulation and aggregate learning spillovers where redistribution is directly growth enhancing. Of particular interest is the possibility that both rich and poor would vote for redistributive policies (either in income or in terms of publicly-provided education) if the external benefits to all classes of having a better educated work force are sufficiently large.

Although it accounts for the negative correlation between inequality and growth found by reduced-form equations, the political economy approach does not appear to be supported by the data. It implies that greater inequality increases the extent of redistribution, which in turns has a direct negative effect on economic growth. A corollary to this is that such a relation should be exclusive to democratic countries. However, Alesina and Rodrik (1994) and Clarke (1993) differentiate between democratic and non-democratic countries in examining the relation between inequality and growth, and fail to find such evidence. Moreover, when measures of redistribution such as tax rates or the extent of social spending are regressed on measures of inequality, the coefficients are either insignificant or have an opposite sign to what the theory

predicts (see Perotti, 1996). It would seem that channels other than the political process must account for the influence of inequality on growth.[17]

7.2 Socio-Political Unrest and Crime

There is also a literature which emphasizes the impacts of inequality of wealth and income on "disruptive" activities such as property crime, riots and armed insurrection (e.g. Gupta, 1990 and Benhabib and Rustichini, 1996). It is argued that absolute and/or relative poverty may motivate people to participate in property crime and that this distorts the allocation of labour effort away from productive activities. Moreover, defensive efforts by potential victims represents a further loss of resources and threats to property rights deter investment. Through these various mechanisms, more inequality may tend to reduce the productivity of an economy. This force may be offset by the endogenous incentive of those in power (the rich, say) to favour redistribution towards the poor in order to reduce crime. Such endogenous redistribution would thereby enhance growth. The relationship between crime and productivity may also vary over time. For example, in Lloyd-Ellis and Marceau (1998) property crime rises in the initial stages of development as the opportunities to gain from illegal activities expand, but falls in later stages as capital market imperfections are overcome and legal activities become more profitable.

The negative effect of weak property rights on productivity and productivity growth is confirmed in the cross-country empirical work of Hall and Jones (1999) and Barro (1999). However, the empirical relationship between inequality and criminal behaviour and between crime and productivity is less clear. This is mainly due to the fact that reported crime statistics are notoriously difficult to interpret because increases in policing tend to increase the rates of reporting and detection and thereby artificially increase the measured crime rate.

[17] Note however that Alesina and Perotti (1994) provide empirical support for the more general hypothesis that high inequality lowers growth because of the political instability it causes.

8. Implications for Human Capital Policy in Canada

A common implication of the theoretical literature discussed above is that inequality-reducing changes in government policy may increase aggregate productivity when two conditions are satisfied:

1. There is market failure or some constraint on the tradeability of a key input to production (e.g. human capital), and
2. The impact of that input on an individual's contribution to aggregate productivity or productivity growth exhibits diminishing returns.

It is worth noting before going further, that if the objective is to raise productivity, redistributive policies need not be the appropriate approach if it is possible to remove the underlying market failure directly. In many circumstances, however, market failures may be so fundamental that no government intervention can correct them (see Hoff, Braverman and Stiglitz, 1993). This is especially true of informational problems and, as noted earlier, the full tradeability of embodied human capital is difficult to imagine.

Given that the removal of the underlying market failure is not feasible, then productivity growth may be enhanced by policies that affect the distribution of wealth or human capital. Here I focus on some key policy implications that can be drawn from the literature reviewed in this primer and which are relevant for Canada.

8.1 The Quality of Public Education and the Persistence of Inequality

Although there undoubtedly exist borrowing constraints on entrepreneurship, this is not the major avenue through which inequality and productivity are linked in advanced economies. For advanced economies, short-term borrowing constraints do not appear to be crucial in determining investments in higher education either. Moreover, since primary and basic education is almost always publicly financed, short-term borrowing constraints do not appear to be directly relevant at this level either.

In contrast, family background is a key determinant of a child's human capital acquisition. Parental incomes and/or parental human capital are complementary to public expenditures in the

production of children's human capital. Although the evidence suggests that short-term borrowing constraints are relatively unimportant for investment in higher education, lack of parental resources are crucially important in the primary and secondary stages of education. This in turn makes it more difficult for children from poorer backgrounds to get to more advanced stages of education and/or training. In effect, this reflects a *long-term borrowing constraint*: it is not possible for parents to borrow against their children's anticipated earnings.

It follows that the level and variation in the quality of primary and secondary education can have profound implications for both the rate of accumulation of human capital and the persistence of inequalities across generations, both of which have implications for productivity growth. Egalitarian systems of primary and secondary education are crucial for raising the aggregate efficiency of human capital investments. In particular, the quality of schools should not reflect the average incomes and social conditions of the local community but, if anything, should compensate for them. Similar implications may arise in the provision of daycare – high quality, egalitarian public systems of daycare can help to reduce the sensitivity of a child's learning and skill development to his/her parent's resources.[18]

Relatedly, given that the quality of schools largely reflects the quality of their teachers, the incentives faced by teachers should not vary across localities. Recent policy discussions have suggested that teacher's pay should be linked to how well their students do on standardized tests. If the social backgrounds of students did not vary across schools this could provide good incentives and attract the best teachers. However, it is clear that average social backgrounds do vary considerably across schools, due to average incomes of local communities, the concentration of recent immigrants in particular areas, etc. In this context, linking pay to outcomes alone could have adverse implications for the persistence of inequality and long term productivity. An effective compensation scheme must take into account the correlation between students backgrounds and their academic outcomes.[19]

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[18] Note however that unlike education, parents may opt out of using public daycare for their own non-financial reasons. If public resources are allocated towards daycare at the expense of schools these children would effectively be discriminated against.

[19] Of course there are many other potential problems in devising such a compensation scheme, not least of which would be how to measure student outcomes in the first place.

8.2 Financing Education: In-Kind versus. Cash Transfers

The most recent evidence does not support the existence of large *static* human capital externalities operating via production, implying that the direct impact of human capital inequality on productivity is also small. However, the key impacts of inequality arise in the process of human capital accumulation itself and depend on the existence of *dynamic* externalities. In particular, because of decreasing returns, high inequality in parental inputs to education reduces average incentives to invest and hence reduces the *growth* in productive human capital. This, in turn, generates greater persistence of inequality and reduces long-run productivity growth.

The existence of dynamic externalities operating through public education implies that there is a potential trade off between taxation or transfers and direct spending. Sufficient direct public spending on education ensures a minimum standard of quality for all and makes it possible for students from disadvantaged backgrounds to advance through the system. However, excessively high taxation to finance this spending may reduce parental inputs to education that are crucially important, especially at early stages. Moreover, if direct spending is financed by reducing transfers or tax-subsidies to the poor, the additional effects of lower average investment in human capital due to greater inequality may offset the positive effects. Ultimately, an optimal government policy must achieve a balance between these effects.

8.3 Public Expenditures at Different Stages of Human Capital Acquisition

Given a fixed total budget, what factors determine the optimal allocation of expenditures between primary, secondary and tertiary education? As usual, the literature implies a trade-off. Greater expenditures on higher education (e.g. hiring of high quality instructors, better facilities and lower tuition costs) may be expected to increase the human capital of those who make it that far through the education system. This can have important "trickle-down effects" by making them more effective managers, engineers, etc. and perhaps most importantly, creative innovators, which will benefit society in general. On the other hand, if such improvements come at the expense of primary and secondary education, it may reduce the incentives for students from disadvantaged backgrounds to get through the system. Thus, higher quality university education may be concentrated among fewer students. The resulting decrease in enrollments and long term

effects of the (persistent) increase in inequality on average human capital accumulation could more than offset the gains.

8.4 The Distribution of Skills and Innovation

Although there are important exceptions, there is growing evidence that the majority of technological innovations are skill-biased. To the extent that the rate of innovation responds endogenously to profit incentives this implies that the distribution of skills (as well as its average level) is an important determinant of R&D investment and other forms of innovation. Given that the innovation or adoption of new ideas and technologies often requires skilled workers, it is crucial for universities, colleges and other institutions of higher and technical learning to be adequately responsive to the technological frontier. Rosenberg (2000), for example, argues that a crucial factor in postwar U.S. growth has been the responsiveness of the higher education system to the needs of industry. However, focussing resources on this stage of the education process at the expense of others need not be the appropriate policy response. Although the innovative process requires skilled labour, implementation of new innovations in production also requires sufficient skills on the part of production and managerial workers. While raising the human capital of those at the top of the skill distribution may reduce the unit costs of innovation, doing so at the expense of those lower down the distribution reduces the ultimate profitability of implementing new technologies. Thus, the maintenance of incentive to innovate requires a balance between the skills of those involved in the innovation or initial adoption of new technologies and those who ultimately implement it.[20]

8.5 On-The-Job Training: Matching Skills with Technology

Many argue that in the current climate of rapid skill-biased technological change, training workers on-the-job to be able to adapt new technologies should be a primary objective for public policy. In the short-run, it may be true that well-targeted expenditures may be effective in this regard. It is likely that the optimal allocation of resources would be skewed towards lower income workers thereby compensating for previous disadvantages in the acquisition of skills via the public education system. In the long run, however, a better allocation might be to direct

[20] This effect is in addition to that described above, where skewing resources towards higher levels of education to raise the skills of those who reach that stage, make it more difficult for others to get this far.

public resources at raising the quality of primary and secondary education. This would enhance students learning abilities and creativity from the beginning, allowing them to adapt to new ideas and technologies more easily. Moreover, the evidence discussed by Heckman and Klenow (1997), for example, suggests that it is be preferable to leave on-the job training to private firms that can ensure a better match between their own needs and the skills learned by workers. Unless there is some evidence of a knowledge externality between firms, it is not clear why such training should be subsidized by the public sector.

9. Conclusions

- Certain fundamental *market failures* (e.g. borrowing constraints, non-tradeability of human capital and knowledge spillovers) exist which play a crucial role in the process of economic development and long-run productivity growth, and which cannot easily be removed by governments.
- In such a world, there are various avenues through which the distribution of wealth and/or human capital can impact upon productivity and productivity growth. However, the key elements are the *lack of tradeability* of a key input to production and the extent of *returns to scale*.
- On balance the evidence suggests that the impact of inequality on productivity growth is largely a *long term* phenomenon, especially in more advanced economies. It operates via implicit long term borrowing constraints and via intergenerational externalities.
- A key mechanism linking inequality and productivity growth is the impact of parental resources on their children's capacity to get the most out of the public education system. Parents provide key *complementary inputs* but typically cannot borrow against their children's anticipated earnings in order to finance them.
- Effective growth-promoting policies are often those that are also equality-promoting, so that a neoclassical "equity-efficiency" trade-off need not be the correct long-run perspective.
- The most cost-effective education policies are those that enhance the capacity of children to get the most out of the public system at an early stage, since this will increase their learning abilities at a later stage. Such policies also tend to be equality-enhancing because they increase the chances that children from disadvantaged backgrounds will get further through the education system.
- Innovation and the initial adoption of new ideas and technology is a crucial source of productivity growth. Although, these activities typically require highly skilled labour, the ultimate implementation of these technologies also requires sufficient, but not necessarily highly sophisticated skills on the part production labour. It follows that satisfying the demand for skills does not, in general, justify skewing public resources towards higher and more scientific education. The maintenance of high incentives to innovate requires a balanced policy approach to influencing the distribution of skills.

Glossary of Terms

Balanced Growth Path: This is a theoretical growth path along which all macroeconomic aggregates (e.g. per capita GDP, physical and human capital, etc.) grow at a constant rate. Although no economy actually grows at a constant rate, the balanced growth path represents the trend towards which the economy would converge in the absence of shocks or policy changes.

Complementary Inputs: Two inputs are complementary if an increase in one raises the marginal productivity of the other. Note that complementarity does not imply the existence of an externality so long as the return to both inputs reflects the impact that each has on the productivity of the other.

Disembodied Knowledge: This refers to knowledge that is generally available to people in the economy and its use by one person does not preclude its use by another. An example is an instruction manual on how to use Windows 2000.

Embodied Knowledge: This refers to knowledge that is specific to an individual and must typically be acquired through a costly learning process (e.g. training or experience). An example is a management consultant's knowledge regarding the human resource problems facing a particular firm.

Endogenous Growth Model: A macroeconomic model of the economy in which the evolution of the factor driving growth (e.g. human capital) is determined by private agents' optimal decisions to allocate inputs (e.g. labour) between activities that generate current consumption (e.g. production) and those which foster greater accumulation of the relevant factor.

Externality: Externalities (or "**spillovers**") are positive or negative effects that one economic agent's actions have on another's welfare which are not regulated by a system of prices.

> **Negative externalities** include pollution and over-fishing in the Atlantic. Both arise because the marginal social cost of the activity exceeds the marginal private cost. Government intervention can take the form of legal limits, taxation or tradeable permits.
>
> **Positive externalities** arise when people do not receive the full benefits of their activities even though they incur the costs (e.g. research and development "spillovers"). In this case, too little of the activity may be undertaken relative to the socially efficient level. Government intervention is often required to supply these **public goods** themselves (e.g. health services), or to provide better incentives to the private sector (e.g. subsidies or patents).
>
> Externalities can also be interpreted as a problem of missing markets for a good. In fact, when we allow for a very broad interpretation of the neoclassical model, we see that missing markets are the major source of market inefficiencies. The neoclassical model assumes that there are competitive markets in which transactions can be made to buy and sell any good for future delivery at every future date, with the prices on those markets being contingent on uncertain events as well.

Functional Distribution refers to fractions of national income accruing to each factor of production – land, labour and capital.

General Purpose Technologies: Refers to technologies, such as the computer, whose application is not specific to a particular sector or industry, but can be adapted and used in many sectors of the economy.

Human Capital: Labour economists typically measure individual human capital using a combination of number of years of schooling and years of experience. More generally we can define human capital to account for the quality of those years in education and training. Neoclassical economists typically adopt a much broader definition which includes knowledge that may be disembodied, but rival.

Idiosyncratic Shocks: These refer to unexpected factors that result in variations in an individual's wealth or income that are not correlated with those of other individuals (e.g. uninsured accidents). Typically the aggregate effect of such shock sums to zero. A recession is not an idiosyncratic shock because it affects all agents. However, there may be an idiosyncratic component associated with a recession (e.g. some people may be more prone to unemployment than others).

Market Failure: Any situation in which the price of a commodity does not equal the marginal cost of producing it. This may be the result of the exercise of market power or due to an externality. Market failures also include situations of market incompleteness where, because of informational problems for example, parties to a transaction may be unwilling to trade (e.g. credit rationing).

Non-Contractible: An input (e.g. labour effort, product quality) is non-contractible if it cannot be unambiguously specified in an ex ante contract or cannot be verified ex post. For example, the effort of an entrepreneur in ensuring that corners are not cut in production cannot in general be observed by a lender and, therefore cannot be included in any meaningful way in the debt-contract.

Production and Non-Production Labour: Conceptually, production labour is intended to represent unskilled labour directly involved in production (e.g. manual labour), whereas non-production labour represents more skilled labour which is not directly involved in production (e.g. management, clerical staff). Empirically, production labour is typically represented by workers who are paid an hourly wage and non-production labour by salaried workers.

Returns to Scale: Refers to the impact of a proportional increase in all inputs on output. If output doubles when all inputs are doubled then there are **constant returns to scale**. If output less than doubles when all inputs are doubled, then there are **decreasing returns to scale**. If output more than doubles when all inputs are doubled, then there **increasing returns to scale**.

Social Efficiency: An allocation of resources is socially efficient when there is no alternative allocation that could make one individual better off without making others worse off. This implies that no resources are wasted.

Size-Distribution of Income: This refers to fractions of individuals or households receiving each income level.

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